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IDENTIFICATION OF COMMERCIAL FERTILIZER MATERIALS.

By William H. Fry, *Scientist in Soil Laboratory Investigations.*

INTRODUCTION.

In working with commercial fertilizers it is often desirable to know not only the percentages of the various ingredients as given by chemical analysis but also the compounds in which these occur in the fertilizer, i. e., the carriers of these ingredients. The calculation of the rational composition from the ultimate analysis in the case of salts gives results which are open to doubt and requires a much more complete analysis than is usually made. In the case of organic materials such a calculation is practically impossible. It, therefore, becomes necessary to identify a great number of the substances occurring in commercial fertilizers by means which give the compounds as distinguished from the chemical ingredients of these compounds.

The following substances were chosen for examination:

Potassium chloride.
Potassium sulphate.
Ammonium sulphate.
Kainite.
Sodium nitrate.
Superphosphate.
Calcium nitrate.
Lime.
Apatite.
Phosphate rock.
Gypsum.
Limestone.
Calcium cyanamid.
Basic slag.
Ground rocks and minerals.
Cottonseed meal.
Raw bone meal.
Steamed bone meal.
Peat, humus, muck, etc.
Dried blood.
Slaughterhouse tankage.
Garbage tankage.
Fish scrap.
Dissolved bone black.
Shells.

Note.—This bulletin gives methods for identifying the carriers of the various fertilizing ingredients, and is intended to serve as a laboratory guide to those studying this phase of the fertilizer question.

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It was found that potassium chloride, potassium sulphate, ammonium sulphate, kainite, sodium nitrate, calcium nitrate, apatite, gypsum, limestone, and other ground rocks and minerals could be identified definitely by microscopic-petrographic methods. For the equipment and modus operandi of determining substances by their optical characters reference is made to the literature of the subject.[1] A brief outline only is here given.

EQUIPMENT.

For the determination of the optical constants of the various salts and consequently for the identification of the salts themselves, a petrographical microscope is practically a necessity. Ordinary microscopes converted into petrographic microscopes by the addition of various adjuncts are clumsy at best and are far from being satisfactory. Petrographic microscopes, as at present manufactured, have reached a high degree of perfection and, considering the quality of the workmanship and their all-round usefulness, the price is not exorbitant. For a full description of these instruments, reference is made to the trade catalogues. A few words concerning them, however, are necessary in order to render intelligible the description of the manipulations used in determining the optic constants.

The petrographic microscope is, in general make-up, similar to ordinary microscopes. It has both coarse and fine adjustments for focusing; the stage is constructed so as to revolve around the axis of the instrument and is graduated into 360°, so that the angle of any revolution may be read off directly. Just below the stage is a condenser lens so fitted that it may be readily thrown in or out at pleasure. Below the condenser lens is a nicol prism which acts as a polarizer, and below the polarizer is the mirror. The objectives are attached to the tube of the microscope by a clamp device which admits of their ready insertion or removal. The objective is centered by two screws acting at right angles to each other. In the tube of the microscope is another nicol prism, the analyzer, which may be thrown in or out of the line of vision and which may be rotated from a position parallel to the polarizer to a position at right angles to it. Between the objective and the analyzer is a slit at an angle of 45° to the planes of the nicols through which various adjuncts are inserted as needed. Above the analyzer is another slit through which another accessory, Bertrand lens, is inserted as needed. The oculars have cross hairs at right angles to each other and parallel to the planes of the nicols.

[1] Bul. 91, Bureau of Soils, U. S. Dept. Agr. Iddings, Rock Minerals. Johannsen, Determination of Rock-Forming Minerals. Rosenbusch and Wülfing, Mikroskopische Physiographie der petrographisch wichtigen Mineralien, 2 vols.

The accessories are a quartz wedge, a quarter undulation mica plate, a gypsum plate, a Bertrand lens, a Bertrand ocular, an eyepiece micrometer, mainly, with others, a description of which, with their uses, will be found in the standard texts.

In examining substances with a view to obtaining their optical constants a series of oils of definite refractive indices are used as embedding mediums. Johannsen [1] gives the following series, which contains oils suitable for practically all purposes:

Refractive indices of various liquids used as embedding mediums.

Liquid.	Index.	Liquid.	Index.
Carbon bisulphide	1.768	Ethylene bromide	1.536
Iodo methylene	1.740	Monochlor benzene	1.527
α—Monobrom naphthalene	1.658	Cedar oil	1.516
α—Monochlor naphthalene	1.639	Benzene	1.501
Mono-iodo benzene	1.621	Xylene	1.495
Cassia oil at 21°	1.606	Beechnut oil	1.477
Cinnamon oil	1.605	Almond oil	1.469
Bromoform	1.588	Carbon tetrachloride	1.466
Monobrom benzene	1.561	Glycerine	1.460
Nitrobenzene	1.554	Amyl alcohol	1.4075
Clove oil	1.544		

Various mixtures of almond oil and cassia oil can be made with refractive indices running from 1.474 to 1.562.

The indices of these liquids vary somewhat on standing, and they should be checked up to at least the second decimal place at occasional periods. Any good refractometer will serve the purpose, or mineral grains of known refractive indices may be used as will be presently explained.

The substance to be examined is mounted on a slide in one of the oils, preferably one of medium index, and covered with a cover glass. It is then ready for observation. If the indices of the liquid and the substance are fairly different the outlines of the particles show up distinctly, and the crystal habit, cleavage angles, color, and so forth, should be noted. Crystallographic and cleavage angles may be approximately measured by aid of the cross hairs and the rotating stage. Efforts should be made to determine whether the color of colored grains is that of the substance itself or of inclusions. High-power lenses will usually accomplish this. However, the majority of the salts are colorless, and consequently color is only rarely of importance. These preliminary observations made, the optic properties of the substance are determined as outlined below.

ISOTROPIC SUBSTANCES.

All substances are either amorphous or crystalline; and all crystalline substances are either isotropic or anisotropic, i. e., they transmit light with equal velocity in all directions or they transmit light with

[1] Rock-Forming Minerals in Thin Sections, pp. 16–18 (1908).

different velocity in different directions. Amorphous substances and substances crystallizing in the isometric system are isotropic. All others are anisotropic. Whether a given substance is isotropic or anisotropic can be readily determined by crossing the nicols; that is, by putting the analyzer in at right angles to the polarizer, and rotating the stage. Isotropic substances remain dark during a complete rotation, whereas anisotropic substances alternately light up and become dark four times during a complete rotation. It should be noted here that sections of anisotropic uniaxial substances cut at right angles to the principal axis remain dark during rotation; but this case can be easily determined by means of interference figures, as will be seen later. Should the substance be isotropic, there remains only the refractive index to be determined.

REFRACTIVE INDEX.

By focusing sharply on an edge of the grain, analyzer out, and then raising the tube of the microscope slightly by means of the fine adjustment, a line of light will be seen to move into or out of the grain. If the refractive index of the grain is higher than that of the oil, the line will move in; if the index of the oil is the higher, the line will move out. In other words, the line of light moves into the medium of higher index on raising the tube. The reverse phenomena takes place on lowering the tube. Another method is to use an objective of medium power with the condenser in and raised. A shadow is thrown across half the field by placing the finger between the reflecting mirror and the polarizer. The grains with an index higher than that of the oil appear dark with a bright band on the side toward the shadow. Should the index of the oil be higher, the bright band is on the side from the shadow. It being known whether the index of the grain or of the oil is the higher, by trial an oil can be found in which the substance completely disappears. The indices of the grain and of the oil are then the same; and since the index of the oil is known, the index of the substance is also known. As a supplementary test, a shadow can be again thrown across the field. Then, the indices of the substance and of the oil being the same, one side of the grain is colored blue and the other red. The isotropic nature of the substance in conjunction with the index of refraction is sufficient to identify it.

ANISOTROPIC SUBSTANCES.

Should the substance be anisotropic, the extinction angles are first measured. This is done by noting the position of the grain when it is completely dark and then rotating it until a crystallographic or a cleavage face is parallel to one of the cross hairs. The angle of rotation read off from the stage is the angle of extinction. A more exact method is that of the Bertrand ocular. This ocular consists of two

right and two left handed quartzes of the same thickness cut perpendicular to the axis. The lines of contact between the four parts are parallel to the principal sections of the nicols. This ocular is inserted in the tube of the microscope in place of the ordinary ocular and a cap nicol placed over it in such a position as to cross the polarizer. The analyzer is out. When a double refracting substance is placed under the microscope with this arrangement, the adjacent quadrants appear dissimilarly colored and the diagonal quadrants similarly colored. Upon rotating the stage a position is reached at which the four quadrants are uniformly colored. Then the principal sections of the grain are parallel to those of the nicols. The angles can be read off as above. In tetragonal, hexagonal, and orthorhombic substances the extinction is always parallel to a crystallographic direction, and consequently the angle of extinction is zero. In monoclinic substances the extinction is parallel or symmetrical only in the zone parallel to the b-axis. The extinction is oblique in all other sections. In triclinic substances the extinction directions are all inclined.

PLEOCHROISM.

Some anisotropic substances possess the property of changing their color or the intensity of their color when rotated under the microscope with the analyzer out. This phenomenon is due to different degrees of absorption in different directions in the crystal. For example, in one direction one color constituent of white light may be absorbed more than another color. The degree of absorption in one direction is expressed as greater, less, or equal to the degree of absorption in another direction; and the absorption axes are assumed to coincide with the axes of vibration of the light.

REFRACTIVE INDICES.

Anisotropic substances belonging to the tetragonal and hexagonal systems have two indices of refraction; and those belonging to the orthorhombic, monoclinic, and triclinic systems have three. These indices may be determined substantially as given for the indices of isotropic substances. One index may be observed in one position of the crystal. The stage is then rotated and another index determined Except in cases of strongly double refracting substances, the determination of the mean index is sufficient for practical purposes.

BIREFRINGENCE.

When the refractive indices are known accurately, the maximum birefringence is obtained directly from them by subtracting the lowest index from the highest. Since, however, it is not always practicable to determine the indices with the required degree of accuracy, other methods are used. The table of Michel-Lévy is here very useful. A copy of it will be found in most textbooks of optical

mineralogy. In its use it is necessary to know the thickness of the grain. To determine this a sharp focus is first made with the fine adjustment of the microscope on the upper surface of the grain and then on the lower surface. The fine adjustment of course must be first calibrated. The value thus obtained is multiplied by the refractive index of the substance, which gives the real thickness. The thickness line is then followed across the table to the color given by the grain between crossed nicols. The nearest oblique line is then followed to the edge of the table, where the birefringence will be found. It should be remembered that this table gives only the maximum birefringence, and consequently it is necessary to try several orientations of the grain in order to be sure that the birefringence obtained is the maximum. Other more elaborate methods for determining birefringence will be found in the standard texts.

OPTICAL CHARACTER OF ELONGATION.

To determine this, the grain is first rotated to extinction between crossed nicols. It is then rotated 45°, thus bringing the interference color to a maximum. For thin plates or weakly refracting crystals a mica plate, for thick sections or strongly refracting crystals a gypsum plate, or quartz wedge, is inserted between the crossed nicols. The vibration directions of these plates must, of course, be known. The colors of the grain will rise to higher orders when similar axes in the grain and plate have the same direction, and will fall when different axes are superimposed. Knowing the directions of vibration in the plate, the directions of vibration in the grain are also known. When the direction of elongation of the crystal is practically the same with the axis of least ease of vibration, the grain has positive elongation. When the direction of elongation of the crystal is practically the same as the axis of greatest ease of vibration, the grain has negative elongation.

UNIAXIAL SUBSTANCES.

All anisotropic substances may be divided, by means of interference figures, into two great classes, uniaxial and biaxial substances. Interference figures are obtained, with good illumination, by using a high-power objective, putting in and raising the condenser lens, crossing the nicols, and removing the ocular. The figure is rendered more distinct by placing over the top of the microscope tube a small blackened disk with a very small aperture through its center. Thus practically all light except that coming from the grain under examination is excluded from the range of vision. The figure may also be seen enlarged by leaving the ocular in and placing a Bertrand lens between it and the analyzer. In the case of uniaxial crystals lying perpendicular to the optic axis, the figure has the form of a dark cross, generally with colored rings around the intersection of the arms of the

cross. When the crystal is so oriented that the section viewed is perfectly perpendicular to the optic axis the center of the cross remains stationary during a complete rotation of the stage. Should the section be slightly inclined, the center will revolve around the intersection of the cross hairs. It may happen that the section is so much inclined that the center of the cross does not appear in the field at all. In this case, a dark bar is seen moving across the field, as the stage is rotated, occupying successive positions parallel one to another and the principal sections of the nicols, followed on further rotation of the stage by a bar perpendicular to the first and also occupying successive parallel positions. In cases where the section viewed is parallel to the optic axis, hyperbolæ are shown which are somewhat similar to those of biaxial figures. However, they do not appear until the stage is nearly in the 90° position. Then they move in, form an indistinct cross, and move out again very rapidly. The hyperbolæ leave the field in the direction of the principal axis.

OPTICAL CHARACTER.

The optical character of uniaxial substances, that is, whether they are optically positive or negative, may be determined by means of the quarter undulation mica plate, the gypsum plate giving red of the first order, quartz or mica wedge, etc. In general the quartz or mica wedge or plate serve the purpose when the center of the interference figure is seen in the field. The interference figure is first obtained and then one of these accessories placed between the objective and the analyzer in the 45° position. In optically positive crystals the colored rings in the NE. and SW. quadrants contract while those in the NW. and SE. quadrants expand. With negative crystals the reverse takes place. It is of course necessary to know the directions of vibration of the plates used. This can always be determined by the same means as those given for crystals by using the plate as an object to be examined. Should the center of the cross be beyond the field of the microscope, a gypsum plate giving red of the first order with the $\mathfrak{a}$ direction parallel to the elongation of the plate is used. Positive crystals show blue in the NE. and SW. quadrants and yellow in the NW. and SE. quadrants. The phenomena are reversed in the case of negative crystals.

BIAXIAL SUBSTANCES.

Biaxial interference figures in sections lying perpendicular to the acute bisectrix, Bx_a, provided the axial angle is less than the field of the microscope, show, when the plane of the axes and the cross hairs coincide, a black cross and a series of colored curves. The points of emergence of the optic axes are indicated by dark spots with colored lemniscates surrounding them and joining at

the center. Upon rotating the stage, the cross dissolves into two hyperbolæ. The convex sides of the hyperbolæ are always toward the acute bisectrix. The smaller the axial angle, the nearer together are the loci of the optic axes; and finally, for very small angles, the interference figure approaches the form of a uniaxial interference figure. When the axial angle is so large that neither of the loci of the optic axes show, the biaxial character is indicated by the movement of the bars.

Sections lying perpendicular to the obtuse bisectrix, Bx_o, show similar figures to those of sections lying perpendicular to the acute bisectrix, provided the axial angle is not too large.

Should the section be inclined to the bisectrix, one of the dark spots may be completely outside of the field of the microscope. The other spot, however, will show, and this is sufficient to determine the biaxial character.

Sections at right angles to an optic axis show a single straight dark bar surrounded by almost circular concentric curves whenever the bar is parallel to the principal planes of the nicols. This bar changes to a hyperbola on rotating the stage, and the convex side is toward the acute bisectrix.

In sections parallel to the plane of the optic axes the interference figure is similar to that of uniaxial crystals parallel to the optic axis. In this case it is advisable to apply a slight pressure with the finger upon one side of the cover glass which causes the crystal to move about into some other orientation which will show one of the interference figures described above.

OPTICAL CHARACTER.

The optical character of biaxial crystals may be determined by means of the mica plate, gypsum plate, and quartz or mica wedge. To use the mica plate, the interference figure is first obtained and the stage rotated until the hyperbolæ form a cross. Upon the insertion of the quarter undulation mica plate, the phenomena are then the same as in uniaxial substances.

Sections perpendicular to the acute bisectrix, the interference figure of which shows no colored curves, are rotated until the hyperbolæ form a cross. The gypsum plate is inserted; and, if its $\mathfrak{a}$ direction is parallel to the elongation of the plate, the center of the field is red and the NE. and SW. quadrants are colored blue while the NW. and SE. quadrants are yellow in positive crystals. The reverse phenomena take place in negative crystals.

If the stage is so rotated that the hyperbolæ form a cross, the phenomena presented on the insertion of a quartz or mica wedge are similar to those of a uniaxial crystal. By remembering that the convex sides of the hyperbolæ are always toward the acute bisectrix,

the optical character of a biaxial crystal can be determined when only one hyperbola appears in the field. The phenomena are similar to those presented when both hyperbolæ appear.

OPTIC AXIAL ANGLES.

In the interference figure of sections cut normal to the acute bisectrix and rotated into the 45° position, the distance between the hyperbolæ, i. e., between the two dark spots, represents the angle between the two optic axes. The observed angle, 2E, however, is not identical with the actual angle, 2V. The symbol 2H is sometimes used to represent the angle when it is measured in an oil. The distance between the points of emergence of the axes, in the 45° position, can be measured by a micrometer eyepiece. Let this distance be 2d. Then

$$\operatorname{Sin} E = \frac{d}{C}.$$

E is half the axial angle in air, d is half the distance between the points of emergence of the optic axes as measured with the eyepiece micrometer, and C is a constant which must be determined for each lens combination. It may be determined by using a mica plate, whose axial angle is known, as an object and substituting in the formula. If n is the mean index of refraction of the mineral, then

$$\operatorname{Sin} V = \frac{\operatorname{Sin} E}{n}.$$

2V can thus be readily found. In a large number of cases the simple designation of the angle as "large" or "small" will serve all purposes; and this relative size may be observed by a glance at the interference figure.

DISPERSION.

Here ρ is used to indicate red light, and υ violet light. Observations are made on the interference figures.

In the orthorhombic system the dispersion is least, $\rho < v$ or $\rho > v$, for the color within the circle which is nearest the bisectrix and which touches the concave side of the hyperbola when the crystal is in the 45° position. The colors are symmetrical to the bisectrix.

In the monoclinic system there are three kinds of dispersion, inclined, horizontal, and crossed. In inclined dispersion the colors are arranged symmetrically to the line joining the loci of the hyperbolæ, but are not symmetrical in the other direction. One locus is oval shaped, larger, and less intense; and the other is round, intense, and smaller. In horizontal dispersion, the colors are not arranged symmetrically to the line joining the loci of the hyporbolæ. They are symmetrical, however, to a line at right angles to this line. In crossed dispersion there is only a point of symmetry.

In the triclinic system the arrangement of colors in the interference figure is unsymmetrical.

In actual determinative work it will seldom be found necessary to determine all of the foregoing optical properties of crystals. But in doubtful cases, the more data available the better; and even in seemingly clear cut cases it is sometimes advisable to make as thorough a study of the substance as possible. The methods described herein are, in general, those of the simplest and most accessible nature, but with their aid and a little practice anyone should soon be able to determine many of the materials ordinarily used in the manufacture of fertilizers. However, it should be remarked that problems continually arise for the solution of which wide experience and a comprehensive knowledge of all theoretical questions involved are none too much.

OPTICAL CONSTANTS OF FERTILIZER MATERIALS.

The diagnostic optical constants of the substances mentioned on page 2 were taken mainly from Dana and Groth[1] and are as follows:

Potassium chloride. Sylvite. KCl.—Isometric. Habit cubic. Cleavage cubic perfect. Refractive index, 1.4903. Sometimes exhibits anomalous double refraction.

Potassium sulphate. Arcanite. K_2SO_4.—Orthorhombic.
Twinning yields pseudohexagonal forms.
Optically positive (+). Ax. pl. ∥ a. B x ⊥ c.
Dispersion feeble, $\rho > v$ oil, $\rho < v$ in air.
Refractive indices, $\alpha = 1.4920$, $\beta = 1.4935$, $\gamma = 1.4970$.
$2V = 66° 30'$, $2E = 109° 57'$.

Ammonium sulphate. Mascagnite. $(NH_4)_2SO_4$.—Orthorhombic. Pseudohexagonal. Optically positive (+). Ax. pl. ∥ b. Bx ⊥ a. Dispersion weak, $\rho < v$. $2E = 87° 44'$, $84° 6'$. $2V = 52° 12'$. Refractive indices, $\alpha = 1.5209$, $\beta = 1.5230$, $\gamma = 1.5330$.

Kainite. $MgSO_4.KCl + 3H_2O$.—Monoclinic. Optically negative (−). Ax. pl. ∥ b. Dispersion inclined, very distinct. $2V = 84° 33'$. $2E = 141°$ approx.

Sodium nitrate.—Rhombohedral. Uniaxial. Optically negative (−). Double refraction strong. Refractive indices for yellow, $\omega = 1.587$, $\varepsilon = 1.336$.

Calcium nitrate. Tetrahydrate. $Ca(NO_3)_2.4H_2O$. Monoclinic. Optically negative (−). Optic angle small. Double refraction high.

Apatite. $(Ca(F,Cl))\ Ca_4(PO_4)_3$.—Hexagonal. Uniaxial. Optically negative (−). Double refraction weak. Refractive indices very close to 1.63.

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[1] Dana, System of Mineralogy. Groth, Chemische Krystallographie.

Gypsum. $CaSO_4 + 2H_2O$.—Monoclinic.

Optically positive (+). Plane of optic axes parallel to (010) at ordinary temperatures.

$Bx A \dot{c} = +52\frac{1}{2}°$. Dispersion inclined strong.

$2V_y = 58° \ 8'$. $2E_r = 95° \ 14'$. Refractive indices, $\alpha = 1.5205$, $\beta = 1.5226$, $\gamma = 1.5296$.

Limestone. Calcite. $CaCO_3$.—Rhombohedral. Uniaxial. Optically negative (−). Double refraction strong. Refractive indices, $\omega = 1.658$, $\varepsilon = 1.486$. *Dolomite,* $(Ca, Mg) CO_3$, is very similar; but the refractive index is greater, $\omega = 1.68$, $\varepsilon = 1.50$. Various chemical tests may be used to distinguish the two.[1]

The mineralogical composition of ground rocks and ground minerals may be ascertained by petrographic methods. On account of the large number of minerals which might be present in such products, reference is here made to the literature already cited for their optical properties.

The above substances are readily differentiated under the microscope. Potassium chloride, being isometric, is isotropic, and consequently remains dark during a complete rotation of the microscope stage between crossed nicols. The refractive index serves as additional evidence and distinguishes this salt from halite (refractive index = 1.54) and other isotropic substances. The remaining substances are divided into two groups by means of interference figures. The rhombohedral and hexagonal substances give uniaxial figures; and the orthorhombic and monoclinic substances give biaxial figures. The uniaxial substances are sodium nitrate, apatite, calcite, and dolomite. All of them are optically negative, and consequently this characteristic does not aid in distinguishing them apart. The determination of the refractive indices, however, readily distinguishes them. The biaxial substances are potassium sulphate, ammonium sulphate, kainite, calcium nitrate, and gypsum. The optical character differentiates these into the optically positive group consisting of potassium sulphate, ammonium sulphate, and gypsum; and the optically negative group, kainite and calcium nitrate. In the former group potassium sulphate is immediately distinguished by its low index of refraction. Ammonium sulphate and gypsum may be distinguished by the other optic constants given. In the optically negative group kainite and calcium nitrate may be distinguished by the difference in size of the optic angle.

Phosphate rock can not be distinguished microscopically as such. But the mineralogic nature of the material, absence of other phosphatic material, and presence of water-insoluble phosphoric acid, jointly, are strong indications of it.

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[1] Iddings, Rock Minerals, p. 34.

Calcium cyanamid, according to L. Vuaflart,[1] may be tested for as follows: "The presence of calcium cyanamid in a mixture containing other fertilizers can be detected by its odor, alkaline reaction, the large amount of calcium present, the black residue which is left after treating the sample with water, and the yellow precipitate obtained with silver nitrate which is insoluble in ammonium hydroxid but soluble in nitric acid. An impurity often present in the latter is a black acetylene silver insoluble in nitric acid. If organic fertilizers are present in the mixture, these can be detected by dissolving the cyanamid in hydrochloric acid, when the organic matter will remain behind as a black residue. Sulphuric acid added to such fertilizers will yield a brown solution."[2]

Basic slag contains a rather large amount of material attracted by an ordinary horseshoe magnet. The nonmagnetic material is transparent under the microscope, with a bluish color. It is anisotropic and biaxial. Tetracalcium phosphate is monoclinic and the double refraction is positive; but this can not always be seen in the commercial material. The refractive index of the transparent commercial material is very near 1.64. The biaxial nature and high index distinguished basic slag from any of the other substances treated of here.

Shells can be easily distinguished by their obvious shelly structure.

Cottonseed meal has a predominantly yellow color with brownish hull particles, and usually some cotton lint. Often it can be detected with the naked eye and is easily identified with the microscope.[3]

Raw bone meal is whitish in color. Mounted in oil, under the microscope, evident bone structure is seen.[4]

Steamed bone meal is very similar to raw bone meal, and it is not always possible absolutely to distinguish the two. The steamed bone may be somewhat darker in color, has a friable appearance, and does not show the sharp angles and edges seen in the raw product. An empyreumatic odor indicates the nature of the material.

Peat, humus, muck, etc., vary very much. The vegetable matter of the material, however, indicates its nature.

Dried blood, megascopically is blackish, dull dark red, and dark purplish in color. It is somewhat brittle. Microchemically blood may be tested for in numerous ways, e. g., the haemin test, guaiacum test, spectroscopic examination of the coloring matter, recognition of blood corpuscles, etc.[5]

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[1] Ann. Falsif., 4 (1911), No. 32, pp. 321–324. Quotation and reference taken from Expt. Sta. Rec., *26*, 804 (1912).

[2] A general discussion of cyanamid will be found in "Cyanamid," by E. J. Pranke, Easton, Pa., 1913.

[3] For details of cell structure and technique see Hanausek-Winton-Barber, The Microscopy of Technical Products, 1907.

[4] Hanausek, loc. cit.

[5] See Allen, Commercial Organic Analysis, Vol. IV, 1898.

Tankage is rather heterogeneous. Particles of bone and other animal matter are present. It has an empyreumatic odor.

Garbage tankage, on account of its extremely various and heterogeneous nature, can not be identified as a unit. Its heterogeniety, however, affords an indication of its nature.

Fish scrap has a characteristic odor. Flesh and bones are present. The general microscopic appearance of the material and its odor will usually serve to identify it.

Lime, both quick and slaked, can be easily identified chemically.

Superphosphate, in addition to water-soluble phosphoric acid and calcium sulphate, contains quartz and various other mineral particles. This can be best seen by leaching the material and studying the residue with the microscope.

Dissolved bone black contains much carbonaceous matter besides phosphoric acid, calcium sulphate, etc.

It thus appears that by far the larger number of the substances examined admit of positive identification. The exceptions are susceptible of such tests as will at least indicate their nature. There seems to be no doubt that by combining microscopic, petrographic, and chemical methods of examination reliable information can be gained as to the nature of the compounds constituting practically all fertilizers.

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